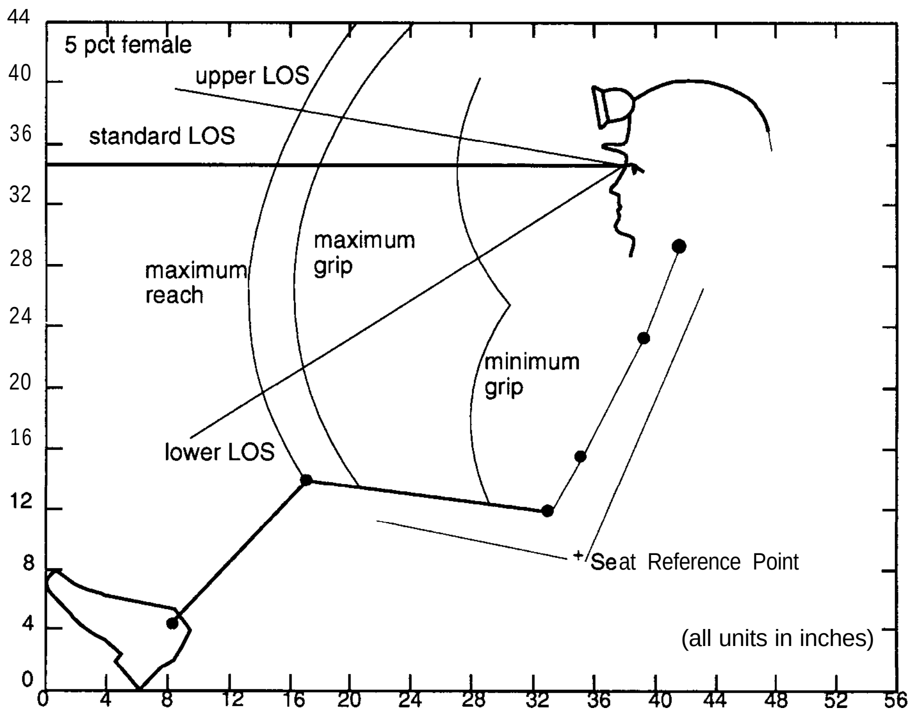
MINING HEALTH AND SAFETY UPDATE

Vol. 1, No. 2 **The latest developments in Federal mine health and safety research** August 1996



Reach envelopes and lines of sight (LOS) for fifth-percentile female operators in 42-inch workstation heights.

Tips for Safer Mining Equipment

Simple design principles can improve equipment safety in mines.

EQUIPMENT IS THE PRIMARY cause of injury in 11% of all mining accidents and a secondary cause in another 10%. Purchasers should select new equipment carefully to ensure that the machine incorporates good ergonomic design criteria that maximize the safety of their mine workers.

One potential problem area is the workstation-the control center of the machine. Safety problems often occur when the workstation provides insufficient clearance or visibility to the operator or has controls that are difficult to reach. This is especially true for underground mines, where confined space is an issue. In reclined or stooped

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What Is Human Factors Research?

- A roof bolter reaches for a lever while guiding the drill with his other hand. Since he's watching the drill and many of the controls look and feel alike, he hits the wrong control and crushes his hand.
- Six hours into the night shift, an ore truck driver dozes off. The truck plows over the berm and down into the pit.
- Fleeing a fire, a face crew sees smoke in the intake entry. Assuming the fire is ahead, they cross over to another entry, but soon encounter even worse smoke.

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This Issue's focus:

HUMAN FACTORS

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Tips for Safer Mining Equipment

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postures, operators will have less strength and agility and often experience reduced visibility.

We have conducted and published much research in Human Factors design of mining machine workstations. This information is currently being compiled into a series of Human Factors design recommendation reports.

The reports will cover many topics, including workstation layout, control design, seating, and visibility. Each topic has a list of basic or first *principles* of design. Understanding these principles is the key to designing or purchasing a workstation that is both safe and efficient. Following is a sampling of these main topics and first principles.

Workstation Layout

❑ The workstation should fit operators from the 5th- to 95th-percentile range. In other words, it should fit all but the smallest 5% and largest 5% of the mining population. Consider the limitations of operators with shorter arms when identifying the arm reach envelope for the location of controls (see schematic on page 1). For clearance requirements for the head, knees, etc., use data from the largest members of the user population.

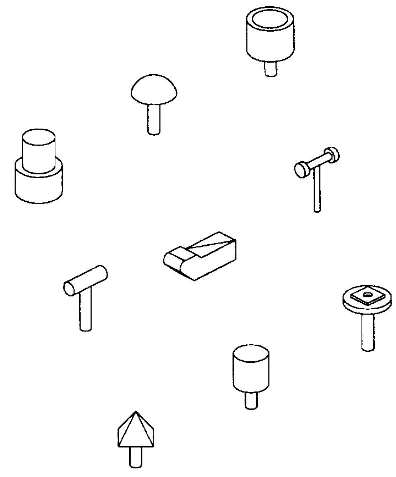
❑ Where practical, distribute the workload as evenly as possible between hands and feet. Position emergency controls and primary controls that require precision operation for easy access by either hand.

❑ Anticipate all potential safety hazards and required emergency actions before starting to design.

❑ Maintain the relative placement of controls and displays for similar types of equipment. This takes advantage of established habits and helps to eliminate confusion when moving from one machine to another.

Control Design

❑ Design controls to comply with anthropometric data on human operators. For example, pushbuttons should be large enough to activate easily with a gloved hand. The force required to engage a panic bar should not exceed the capabilities of the operator in his or her normal operating position.



Several recommended knob shapes for roof bolters wearing gloves.

❑ Ensure that the operator can identify the proper controls quickly and accurately. For example, critical controls should be larger than noncritical controls.

❑ Where feasible, the speed of a vehicle or component should be proportional to the displacement of the control from its rest position and in the same direction.

❑ Controls should have sufficient resistance to reduce the possibility of inadvertent activation by the weight of a hand or foot.

❑ Design controls to withstand or guard against abuse, such as from falling roof and ribs or from the forces imposed during a panic response in an emergency stop. Also, design control surfaces to prevent slipping.

Seating

❑ The seat should fit and adjust to body dimensions, distribute weight

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UPDATE

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to relieve pressure points, and support posture. In other words, the seat should be comfortable.

❑ The seat should provide design features to guard against shocks caused by rough roadways and minor collisions that tend to unseat a person.

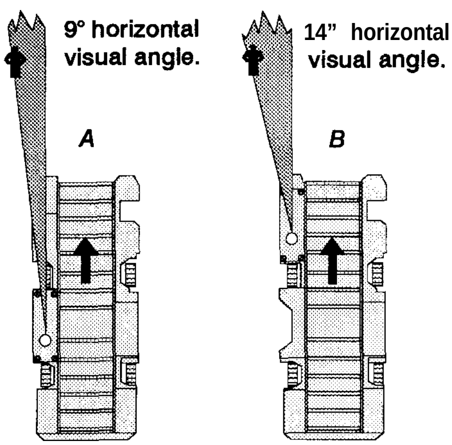
❑ The seat should not hinder the operator's ability to control the machine. For example, the seat back should not interfere with shoulder movement.

❑ The seat should not hinder the operator's ability to enter or exit the workstation. For example, it should be possible to move arm rests out of the way.

❑ Design the seat so that mine personnel can easily maintain or replace it. Use modular components when possible.

Visibility

❑ The workstation should provide an unobstructed line of site to locations or objects that should be visible to perform a job safely and efficiently.



Shuttle car *A* requires a smaller visual angle to see an obstruction than shuttle car B.

❑ Provide enough contrast between the luminance of the object or location of interest and the surrounding background to ensure that the task can be performed safely and efficiently.

Our design recommendations will be useful to everyone in the industry, not just machine designers. For instance, the first report will include a Maintainability Design Checklist for coal mining equipment. The checklist provides a summary of design review points so that equipment buyers can evaluate the maintainability of new or existing underground equipment. It specifically focuses on identifying design features that impact downtime, repair costs, labor hours, and maintenance expertise required.

Our first recommendation report will be published in late 1996 and will cover underground mobile mining equipment. A subsequent report will address surface mining equipment. The report will also be published as a World Wide Web page on the Internet (accessible via http://www.usbm.gov). Users contacting the web page will be able to pose questions directly to experts in Human Factors design.

Richard L. Unger, Civil Engineer, (412) 892-4372 (ungerrl@ptmba.usbm.gov). ■

What Is Human Factors Research?

CONTINUED FROM PAGE 1

These very different accidents have at least one factor in common: the human factor. The actions, decisions, thoughts, or perceptions of one or more humans contributed to the accident. These are just a few examples of safety problems researched by the Human Factors Group of the Pittsburgh Research Center.

Human Factors is a young science that emerged during the late 1950's and early 1960's. Its practitioners study human abilities and characteristics, and work to apply that information to the safe design and operation of equipment, systems, and jobs. By taking the strengths and limitations of human beings into consideration, Human Factors designers can make jobs safer, more productive, and more rewarding.

Human Factors research in mining started over 20 years ago. The Federal Coal Mine Health and Safety Act of 1969 spawned new studies of industrial safety problems in mining. These studies showed that 50% to 85% of all mining injuries are due, in large part, to human error. The evidence suggested that poorly designed equipment, work environments, and ineffective training are often the cause of these performance errors.

Human Factors designers can make jobs safer, more productive, and more rewarding.

This led to the formation of a specialized Human Factors research program. Today, our group employs more than 20 experts in industrial engineering, social sciences, computers, biomechanics, education, training, and other related disciplines. These researchers work in teams to address safety problems and provide usable solutions to the mining community.

Some examples of useful products or information that we've developed include—

- How to lift without hurting your back. Or better yet, how to get the job done without dangerous lifting.
- An improved method for donning a self-rescuer in a mine fire (the "3+3 method").
- Software that lets you design a permissible illumination system for a mining machine while maximizing visibility.
- Training exercises that use three-dimensional slides to teach miners how to recognize hazardous roof.
- How to implement new technologies, such as automation: what works and what doesn't.

This newsletter describes several of our research products in greater detail. We hope to show you many more in future issues. If you have suggestions for new research areas or want more information on what we've already done, please feel free to contact us.

Robert F. Randolph, Research Psychologist, (412) 892-4360 (randolrf@ptbma.usbm.gov). ■

From the Editor. . .

The Pittsburgh Research Center (PRC) and Spokane Research Center (SRC) are among the world's foremost mining research establishments. We conduct research to promote the health and safety of the Nation's mine workers. Once a part of the former U.S. Bureau of Mines, work at PRC **and SRC** was transferred to the U.S. Department of Energy (DOE) in April 1996. As part of the fiscal year 97 budget, health and safety research at PRC and SRC will be transferred to the National Institute for Occupational Safety and Health (NIOSH).

Mining *Health and Safety* Update will be issued periodically on different topics to apprise our readers of tangible research results and to expedite the transfer of new technologies to our customers. Each section of the Update will describe what's new or changed in relation to current practices or technologies in mines today.

On the back page of this Update is a Reader Response Form. If you wish to receive future issues of the Update, you must return this Response Form. Please take a few minutes to respond. We are open to your contributions, suggestions, and questions at any time to formulate the direction of our research.

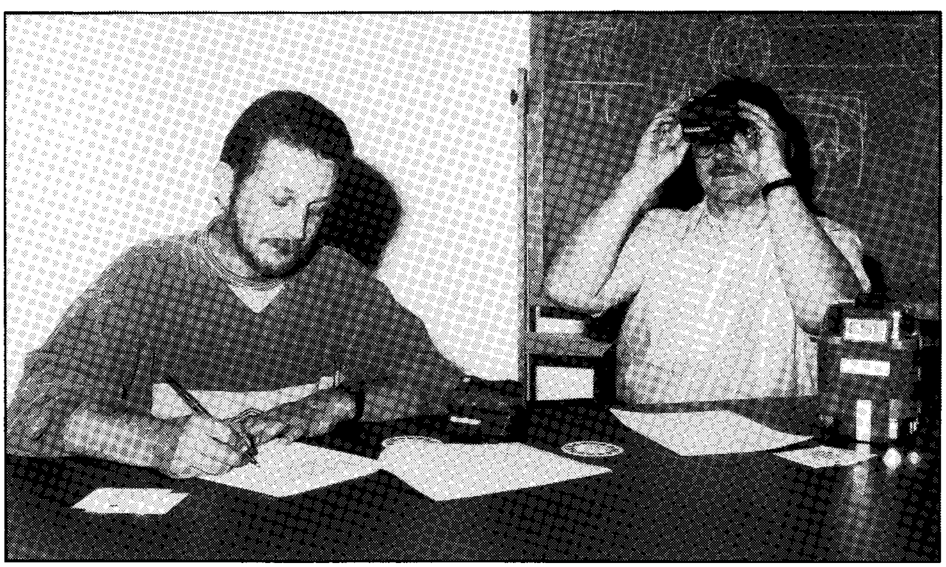
Requests for back issues should be directed to Rose Ann Crotsley, (412) 892-6609 (crotslra@ptbma.usbm.gov).

Training

Latent-Image Simulation Exercises

LOOKING FOR NEW MATERIALS for refresher training? Since the 1980's the University of Kentucky and the Human Factors Group of the Pittsburgh Research Center have developed 70 different latent-image simulation exercises, covering areas as diverse as sexual harassment, a diving injury, first aid in confined spaces, and hazard recognition at surface operations.

These exercises are performance-based instructional materials for teaching problem-solving skills to miners. Each exercise tells a story, then lets the trainee make decisions to resolve the problem using latent-image answer sheets. "Latent-image" refers to a process where words are printed on paper with invisible ink. The words are revealed when a special pen is used to draw over them. That text explains whether the response was correct and the consequences of the response selected. One recently developed exercise combines latent-image technology with three-dimensional slides to address machine guarding hazards



The Pittsburgh Research Center has developed training simulations using latent-image exercises and Viewmaster three-dimensional slide reels to enhance the hazard recognition skills of miners. ***(Photo by John J. Haggerty)***

and safety practices. "Raggs and Curly" follows Raggs (a chief mechanic) and Curly (his helper) as they evaluate the effectiveness of machine guards at a surface coal mine and discuss safe machine guarding practices. The exercise develops skills in machine and equipment safeguarding strategies, hazard identification, proper use of warning and caution signs, safe work procedures, and safe machine guarding practices. It also reinforces important principles in guard design and construction.

Latent-image exercises offer a new approach to training through problem solving, are fun to do, and offer several advantages over traditional classroom training. These advantages include an unfolding of information and consequences, immediate corrective feedback pertaining to the participant's answer choice, and active group participation in learning. To date, about 500,000 copies of the exercises have been distributed.

Latent-image exercises offer a new approach to training through problem solving and offer several advantages over traditional classroom training.

For a list of available latent-image exercises, request a copy of the *Catalog of Training Products for the Mining Industry - 1996* from MSHA's National Mine Health and Safety Academy, Beckley, WV, at (304) 256-3257. For information on the research that led to the development of the latent-image exercises, contact Roberta A. Calhoun at (412) 892-4352.

Lynn L. Rethi, Training Research Specialist, (412) 892-6686 (rethill@ptbma.usbm.gov) and Charles Vaught, Research Sociologist, (412) 892-6830 (vaughtc@ptbma.usbm.gov). ■

Products

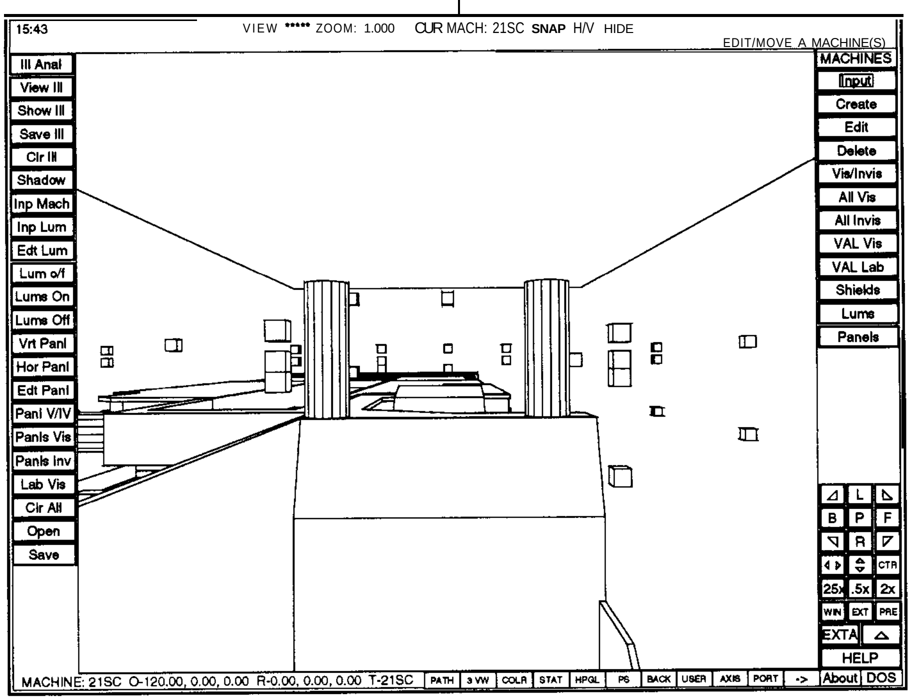
Crewstation Analysis Programs

THE CREWSTATION ANALYSIS Programs (CAP) is a software package for determining whether a mining machine provides adequate visibility and illumination to operate the machine safely. CAP was designed for use by original equipment manufacturers and purchasers of their equipment. It can assess visibility for shuttle cars, scoops, and continuous miners and can measure illumination for any type of equipment.

The visibility model can assess visibility for an operator of any size. It determines whether that operator can "see" a set of visual attention locations (VAL's). VAL's are points in space that must be visible to operate the equipment safely. For example, the operator must be able to see an obstruction in the roadway in time to avoid a collision.

The illumination model can quickly assess lighting systems for underground mines. First, the user selects the luminaires and identifies their locations on the machine or surrounding environment. The model then computes the resulting illumination around the machine using methods compatible with MSHA's Statement of Test and Evaluation (STE). In fact, users can submit the CAP output directly to MSHA for certification. This computerized technique lets users test alternate lighting system designs quickly without the expense and inconsistency of mine lighting laboratory mockups. Users can also determine the effects of modifying a lighting system on operator visibility while the machine remains in service. A future update to the software will let the user optimize illumination while reducing disabling glare. Currently, CAP is available for the DOS platform. However, a Windows 95 version is under development.

Richard L. Unger, Civil Engineer, (412) 892-4372 (ungerrl@ptbma.usbm.gov). ■



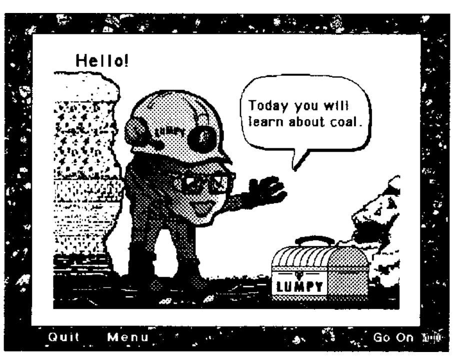
Eye view of a 95th-percentile male operator seated in a 21SC shuttle car (cubes indicate VAL's).

Coal County

COAL COUNTRY is an interactive, educational computer program designed to teach elementary school children the importance of coal to our society. However, technical presentations have shown that it appeals to all ages. The software includes four modules: How Coal Is Formed, Where Coal Is Found, How Coal Is Mined, and How Coal Is Used.

Each module is 5-8 minutes long and can be viewed separately or as a total educational unit. The modules use pictures, sound, and animation to hold the students' interest. Students interact with the software by responding to specific questions related to the material covered. Experts in mining engineering, geology, electrical engineering, mechanical engineering, education, and psychology served as reviewers to evaluate the content, flow, and ease of use. Comments by teachers and children showed that the program was well received. "It *helped the children understand how coal is formed and why this natural resource is important."* One child's response: "I *loved it. It got me interested in coal."*

We developed "Coal Country" in cooperation with the Bethel Park, PA, Public Schools and the Center for Economic and Energy Development. "Coal Country is available in either Macintosh or Windows format. A sound card is optional, but is necessary to hear the music and other sound effects.



"Lumpy" is a cartoon character that guides students through four lessons in Coal Country.

The cost of the software, which includes online documentation of suggested classroom activities, is $7.50 (orders of more than 100 are available for $5.00 per copy). Orders can be placed through either of the following sources:

The American Coal Foundation
1130 17th Street, NW.
Suite 220
Washington, DC 20036
(202) 466-8630

SME Foundation
8307 Shaffer Parkway
Littleton, CO 80127
(303) 973-9550

Kathleen *M. Kowalski, Research Psychologist, (412) 892-4021* (kowalskm@ptbma.usbm.gov) . ■

Did You Know?

- Roof fall fatalities in underground coal mines have decreased significantly. From 1990-92, 50 miners lost their lives to roof falls. From 1993-95, 24 such fatalities occurred, a decrease of more than 50%!
- From 1992-94, independent contractor employees comprised 15% of the work force at surface coal mines, yet they accounted for 45% of the fatal accidents. Leading cause of death? Powered haulage accidents. Primary occupation of the victims? Truck driver.

Barbara Fotta, Research Methodologist, (412) 892-6653 (fottab@ptmba.usbm.gov).

Upcoming Human Factors Presentations

Oct. *15-17, 1996* • **National Mine Instructors'** Conference, **MSHA National Mine Health and Safety Adademy, Beckley, WV (registration: Linda Elswick, (304) 256-3252).** *How To Combine Smoke Drills and Hands-on SCSR Training (L. Mallett), Mining Health and* Safety on the *Internet (R. Randolph), Accident Trends in the Mining Industry (L. Rethi, B. Fotta), Characteristics of Leaders in Escape From Three Underground Mine Fires (K. Kowalski and M. Bmich), Principles and Methods* of *Problem Identification (L. Steiner and K. Cornelius), Applied Research* To *Enhance the Training and Performance of Tracked Dozer Operators (W. Wiehagen and T. Friend).*

Nov. 14-15,1996 • **Kentucky Mining Institute, Lexington, KY (registration: Bill Caylor, Kentucky Coal Assn. (606) 233-4743, http://www.miningusa.com).** *Extended-Cut Effects on Ground Control and Face Crew Safety (L. Steiner and E. Bauer), Mobile* Roof *Support Usage and Retreat Mining Safety (F. Chase and* **F.** *Turin), Safety Trends in Appalachian Coal Mining (B. Fotta and F. Turin).*

Nov. 17-22, 1996 • **1996 International Mechanical Engineering Congress and Exposition, Atlanta, GA (registration: (800) 843-2764 (USA); (212) 705-7788 (international); http://www.asme.org).** *Poster presentation: Trunk Extension and Flexion in Standing and Kneeling Postures: Peak Torque and Associated Electromyography* of *Ten Trunk Muscles (S. Gallagher and C. Hamrick).*

Dec. 2-13, 1996 • Minesim '96 - First International Symposium on Mine Simulation via the Internet. No conference location; papers will be published on the Internet (registration: http://www.metal.ntua.gr/msslab/MineSim96). *Computerized Mine Emergency Response Simulation (M. Brnich, A. Glowacki, L. Mallett, R. Unger, and C. Vaught).*

Dec. 11, 1996 • Midwest Technology Transfer for Underground Stone Roof and Rib Control, Paducah, KY (registration: Lou Prosser (412) 892-4423). *Recognition Training in Underground Limestone Mines (K. Kowalski, L. Rethi, and E. Barrett).*

Recent Human Factors Publications

Barrett, E. A., and K. M. Kowalski. *Effective Hazard Recognition Training Using a Latent-Image, Three-Dimensional Slide Simulation Exercise.* USBM RI 9527, 1995, 36 pp.

Barrett, E. A., L. L. Rethi, and B. Fotta. *Elements From Comprehensive Safety Programs in General Industry Could Benefit Independent Contractors Working in the Mining Industry (Part 1).* Holmes Safety Assoc. Bull., Mar. 1996, pp. 1-6.

Barrett, E. A., L. L. Rethi, and B. Fotta. *Elements From Comprehensive Safety Programs in General Industry Could Benefit Independent Contractors Working in the Mining Industry (Part 2).* Holmes Safety Assoc. Bull., Apr. 1996, pp. l-6.

Fotta, B., F. C. Turin, and J. N. Murphy. *Appalachian Coal-Mining Health and Safety Trends.* Min. Eng., Dec. 1995, pp. 1115-1119.

Gallagher, S., A. G. Mayton, R. L. Unger, C. A. Hamrick, and P. Sorrier. *Computer Design and Evaluation Tool for Illuminating Underground Coal Mining Equipment.* J. of the Illuminating Eng. Soc., v. 25, winter 1996, pp. 3-12.

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Glowacki, A. F. *Using MADSS To Analyze Mining Accident Trends on a Personal Computer.* Paper in Proceedings of the 26th Annu. Inst. on Mining Health, Safety, and Research. VA Polytechnic Inst., Blacksburg, VA, Aug. 28-30, 1995, pp. 133-140.

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Perdue, C. W., K. M. Kowalski, and E. A. Barrett. *Hazard Recognition in Mining: A Psychological Perspective.* USBM IC 9422, 1995, 44 pp.

Peters, R. H. *Encouraging Self-Protective Employee Behavior: What Do We Do?* Paper in Proceedings of the 26th Annu. Inst. on Min. Health, Safety, and Res. VA Polytechnic Inst., Blacksburg, VA, Aug. 28-30, 1995, pp. 83-94.

Randolph, R. F., and L. J. Steiner. *Mining Health and Safety on the Internet.* Paper in Proceedings of the 5th Conf. on the Use of Computers in the Coal Industry, Morgantown, WV, June 9-12, 1996, p. 178-184.

Turin, F. C., and others. *Human Factors Analysis of Roof Bolting Hazards in Underground Coal Mines.* USBM RI 9568, 1995, 25 pp.

Vaught, C., B. Fotta, W. J. Wiehagen, R. S. Conti, and R. S. Fowkes. *A Profile of Workers' Experiences and Preparedness in Responding to Underground Mine Fires.* USBM RI 9584, 1996, 31 pp.

Wiehagen, W. J., G. T. Lineberry, and L. L. Rethi. *The Work Crew Performance Model: A Method for Defining and Building Upon the Expertise Within an Experienced Work Force.* SME, v. 298, Feb. 1996, pp. 1925-1931.

Copies of the above publications may be obtained by contacting: Mildred C. Miller, (412) 892-4321 (millermc@ptbma.usbm.gov).

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